INRA
SCIENCE & IMPACT

Impact of biogas digestate typology on nutrient recovery for plant growth: accessibility indicators for fertilization prediction

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« Reverse engeneering» concept

Environmental constraints

Environment water – air – soil

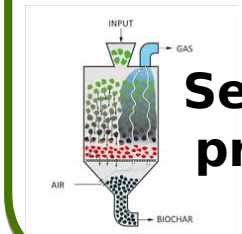
Organic residues

al Biorefinery

Targeted services





Several processes

CH_4


Compromise management

soil & plant

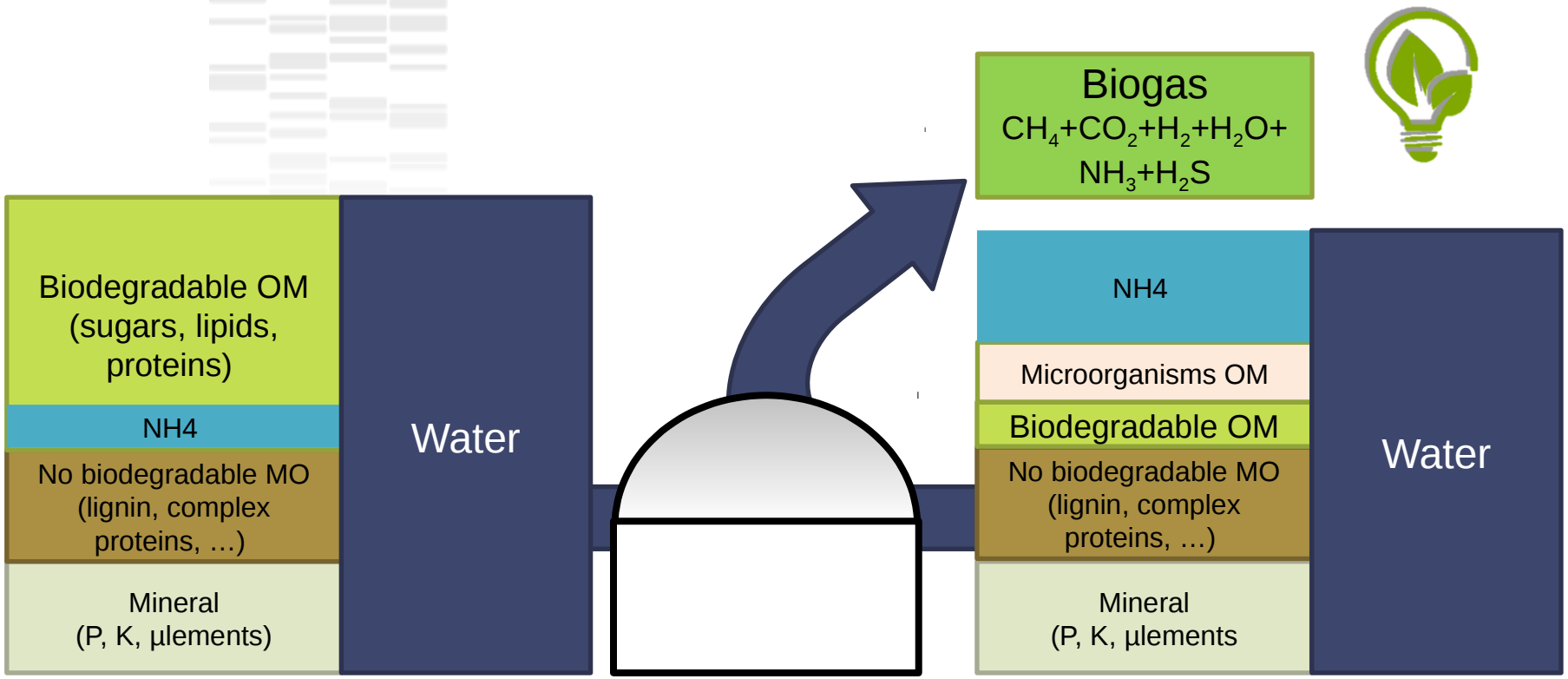
Input management

Process and conditions Treatment train conception

Typology quality / safety

Needs of the agrosyste

Anaerobic digestion: energy and agronomical value

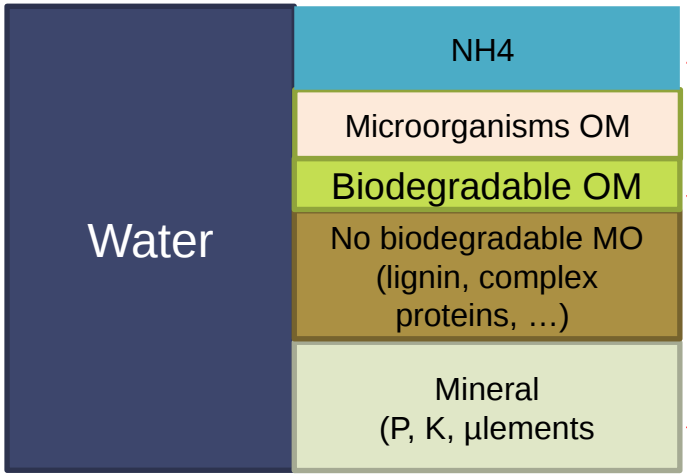


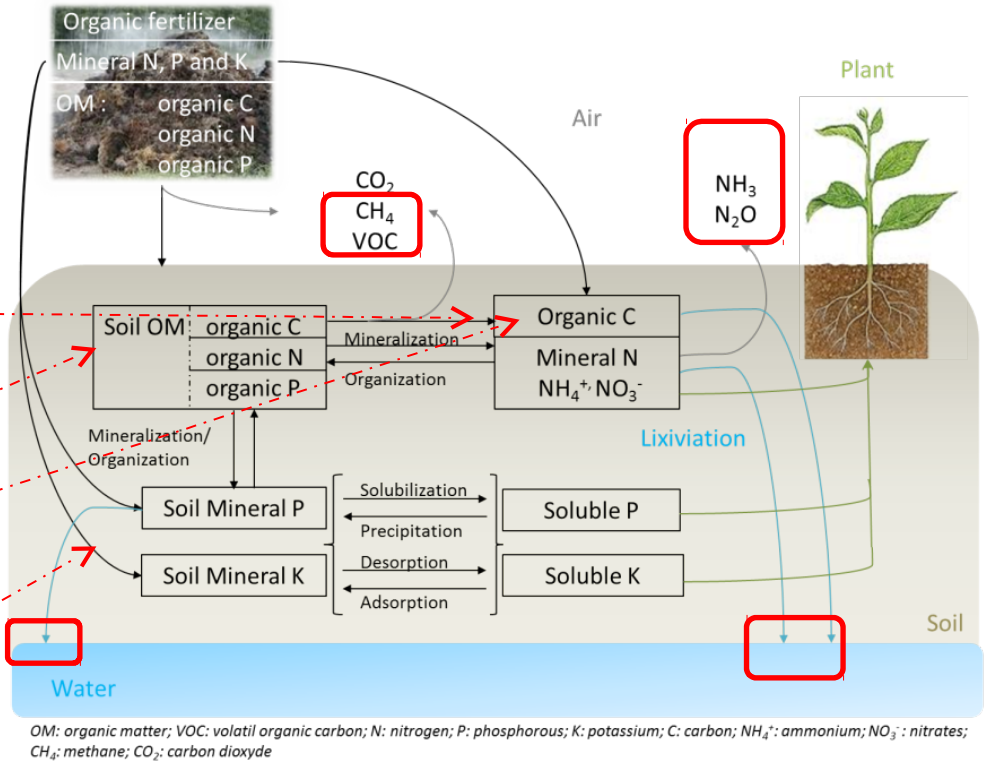
Substrate, raw matter

Anaerobic digestion

Raw digestate

Anaerobic digestion: agronomical value





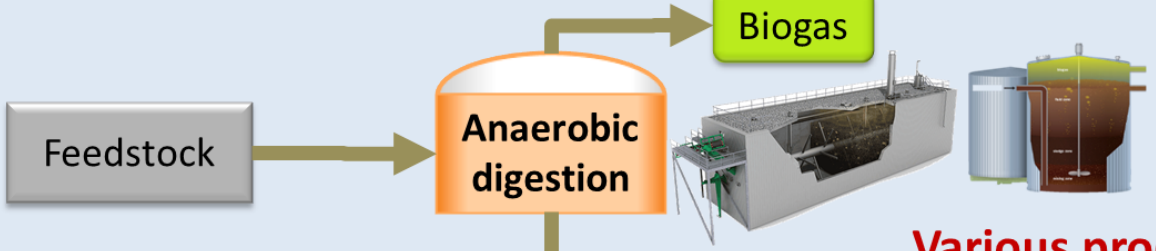
Raw digestate

All the ingredients are present!

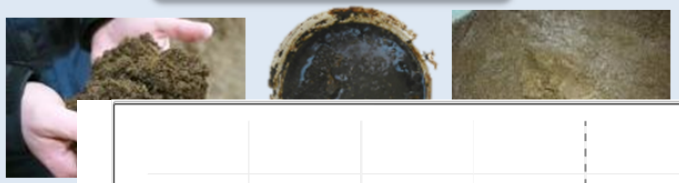
State? Availability, accessibility? Stability? Toxicity? Environment effects?

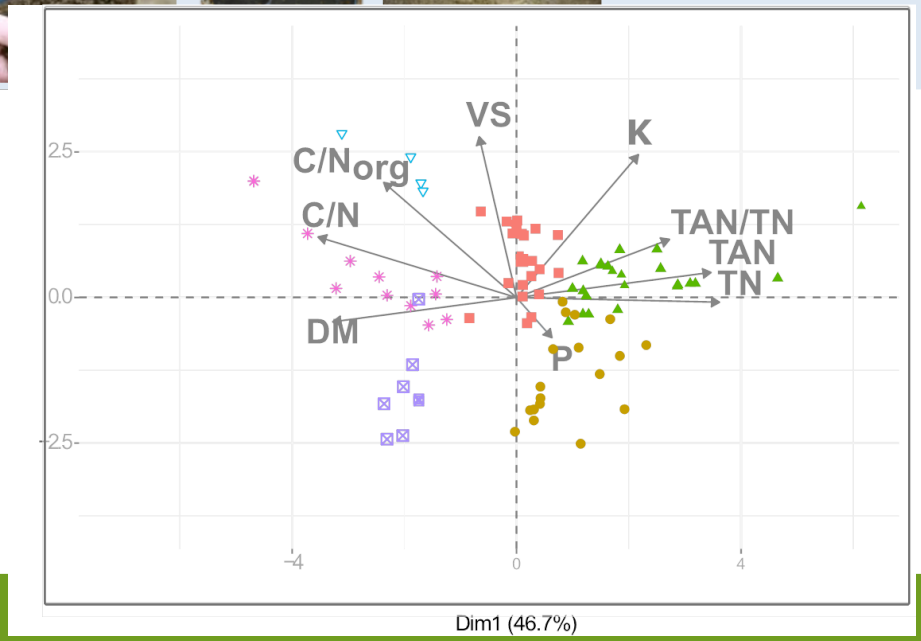
Digestates quality variability

Various inputs



= High **quality variability**





Digestate types

- 1. Fibrous feedstock: Cattle slurry, silage mono/co−dig.(n=19/22)
- 2. Sewage sludge, Biowaste, FAI mono/co−digestion (n=18/19)
- 3. OFMSW, Food Waste, FAI, Pig slurry mono/co−digestion (n=23/23)
- 4. Manure/other co−digestion (n=4/4)
- 5. OFMSW and Biowaste mono/co−digestion (n=6/8)
- 6. Fibrous feedstock: Cattle manure, green waste, silage (n=11/11)

Guilayn et al. (2019). Valorization of non-agricultural digestates: a review for achieving added-value products.

Questions and strategy proposed

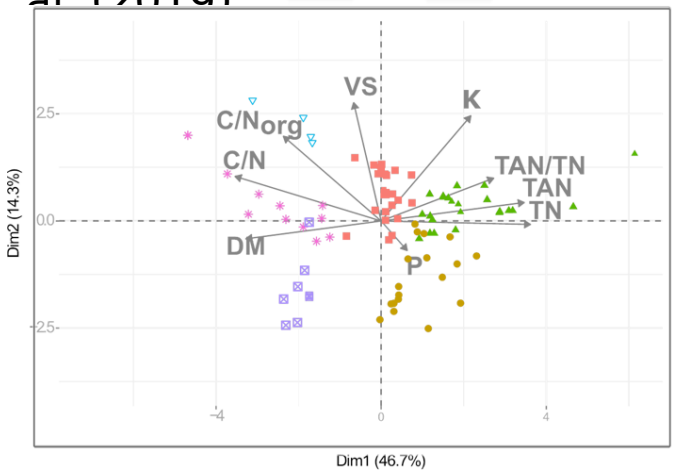
Focus on biogas digestates agronomic value….

- Digestates are able to substitute all or in part N and P chemical fertilizers:
  - Is it possible to find some characterization indicators to predict N and P availability on soil?
  - Has the typology of digestates an impact on N and P availability for soil and plants? How?
- **Strategy proposed:**
  - Perform soil incubations and plant pot trials to better understand the digestates N and P fate after land spreading
  - Apply existing chemical accessibility characterization to digestates: N and P speciation
  - Use digestates sample from different typologies

Material and Methods

Digestates samples choice

Digestates typology by Guilayn et al. (2019)

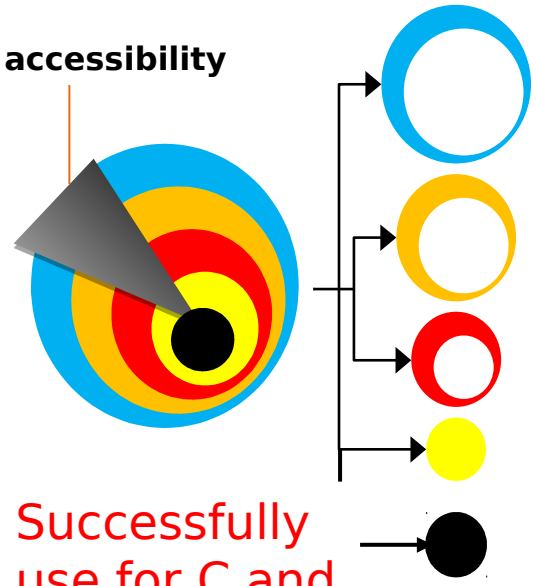


Name	Origin
Agri_1	Dry batch AD of cow manure
Agri_2	Liquid AD of pig manure
Agri_3	Dry Batch AD of wheat straw
Sludge_1	Liquid AD of wastewater sludge
Sludge_2	Compost of digestate
FFMSW_1	Dry AD of municipal wastes
FFMSW_2	Compost of dry continuous AD of municipal wastes
BW_1	Liquid AD of biowastes
Centr_1	Liquid phase of a AD of centralised (mainly agro-industrial substrate)
Centr_2	Solid phase of a AD of centralised (mainly agro-industrial substrate) as

D1, D2, BD: *Data from Grigatti et al. 2019 -> P*

Material and Methods

Global analysis : TS, VS, C, P (ICP), N (N et C: elementary analysis)
Accessibility characterization:



N

SPOM: Available proteins and NH_4^+
Deionized water +CaCl2 (10mM), T=30°C x2 (1h)

REOM: low bounded proteins
NaCl+NaOH (10mM), T=30°C x 4 (15min)

SEOM: complex proteins and humic acids-like
NaOH (1M), T=30°C x 4 (1h)

PEOM: non accessible N
H2SO4 (72%), T=30°C x 2 (3h)

NEOM: non extractible N

P

Water-P: Available P
Deionized water, ambient T, x1 (24h)

NaHCO3-P: labile P
Na… (0.5M), pH= 8.5, ambient T, x1 (24h)

NaOH-P: Metal bounded P
NaOH (0.1M), ambient T, x1 (24h)

HCl-P: Ca bounded P
HCl (1M), ambient T, x1 (24h)

…NEOM-P: non extractible P

Extraction power

Successfully use for C and N bioaccessibility in AD


Bioresource Technology
Volume 241, October 2017, Pages 1012-1021

Methane production and fertilizing value of organic waste: Organic matter characterization for a better prediction of valorization pathways

Julie Jimenez [a], Han Lei [a], Jean-Philippe Steyer [a], Sabine Houot [b], Dominique Patureau [a]

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https://doi.org/10.1016/j.biortech.2017.05.176

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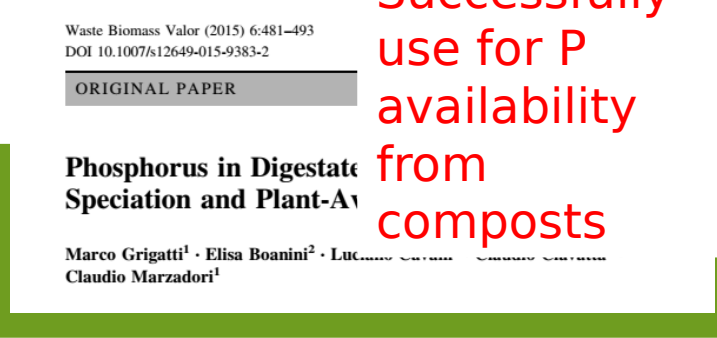
Waste Biomass Valor (2015) 6:481–493
DOI 10.1007/s12649-015-9383-2

ORIGINAL PAPER

Phosphorus in Digestate… Speciation and Plant-Av…

Marco Grigatti[1] · Elisa Boanini[2] · Luc… Claudio Marzadori[1]

Successfully use for P availability from composts

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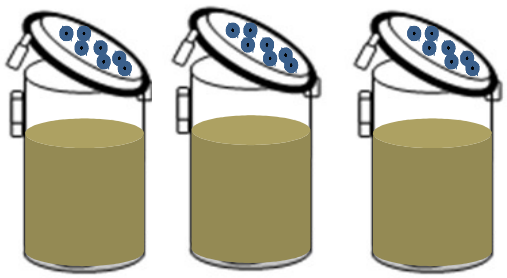
Material and Methods

Soil Incubations



- **250 g** of soil in 3 replicates, 25°C;
- Digestate/soil rate of **170 kg N ha^{-1}**
- Chemical reference Ctrl + : N (as NH_4NO_3) and P and K (as KH_2PO_4)
- A non-treated soil Ctrl-

- **Olsen-P**: Soil samples collected at day: **0, 14, 28, 56, 84** and extracted with 0.5 M NaHCO3 (pH 8.5), 30 min
- **Mineral N**: Soil samples collected at days **0, 14, 28, 56 and 84** with 1M KCl for 30 min

Plant pot trials

- **1 kg** of each different treated soil in 3 replicates.
- **0.8 g of seeds of Italian ryegrass** *(Lolium multiflorum subsp. Italicum), cv. Sprint*

- Harvest: ryegrass plants cut collected **at 28, 56 and 84 days** -> ***Shoots***
- **84 days: *Roots***

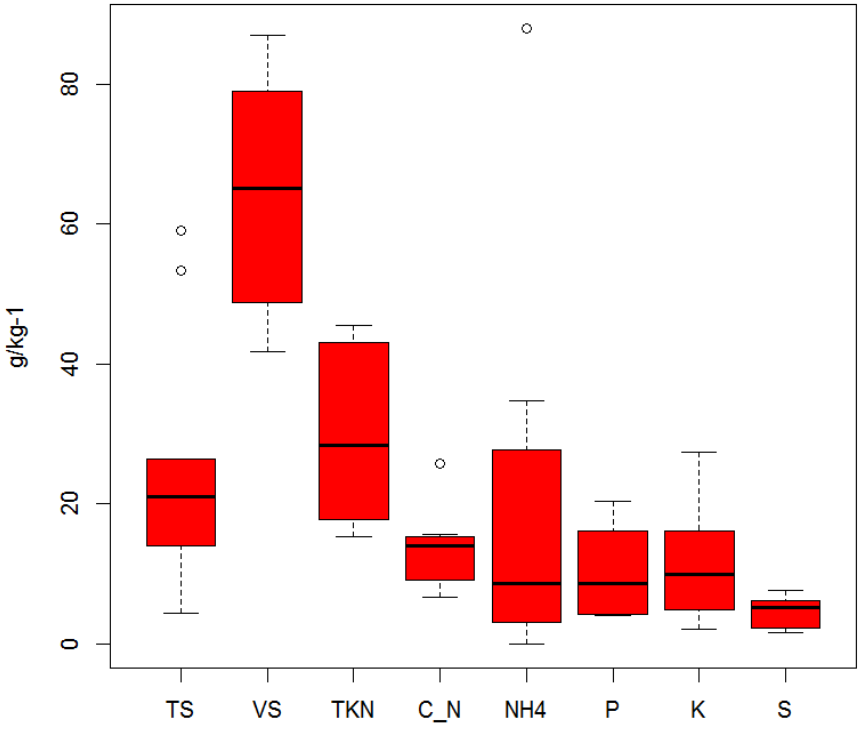
- Analysis on plant tissues:

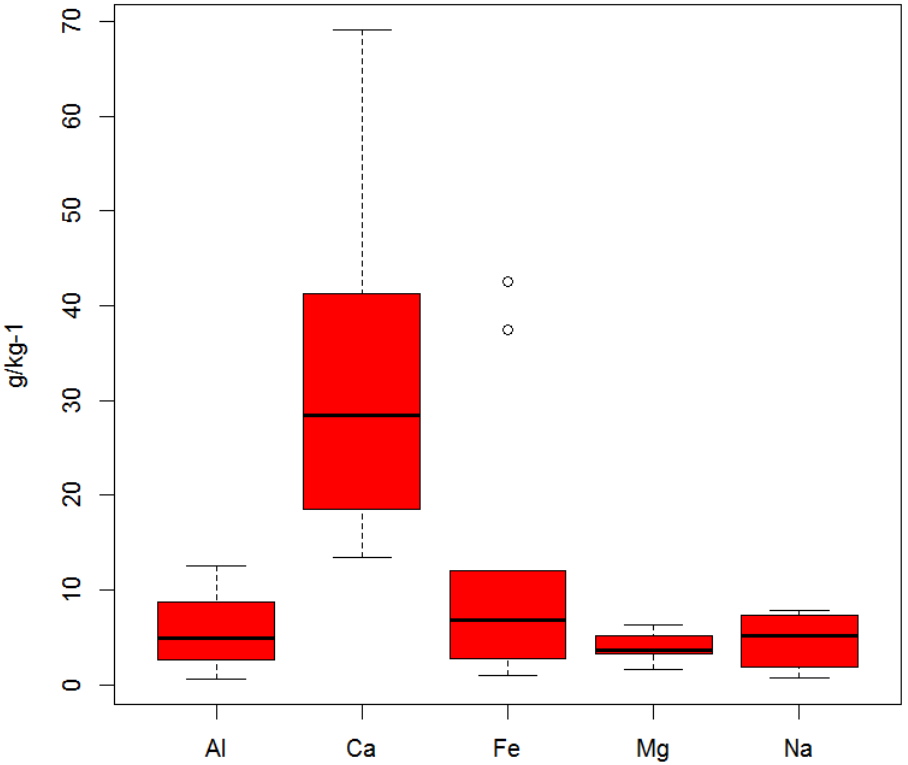
DW (dry weight), P(ICP), N (elementar analysis)

All the samples were freeze-dried and grounded at 1mm -> reduce the particle size effect in the incubation and in plant growth experiments

Results

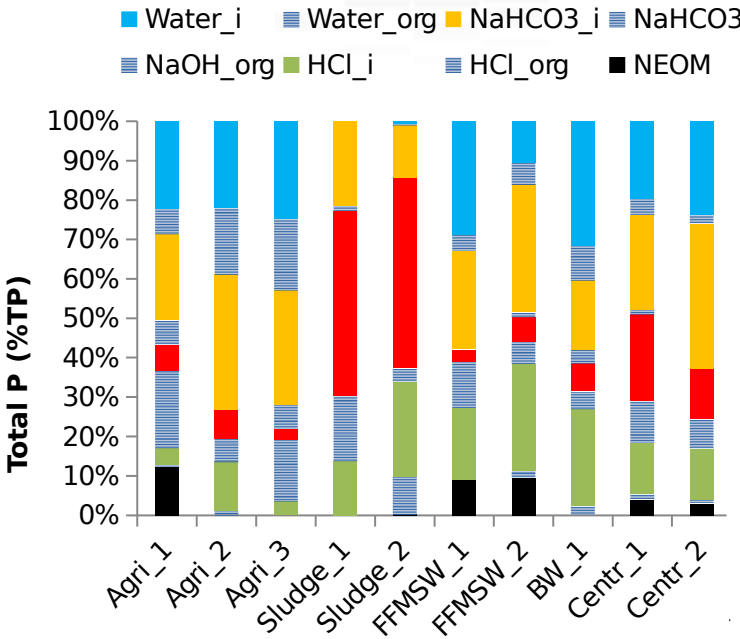
Digestates characterization and variability

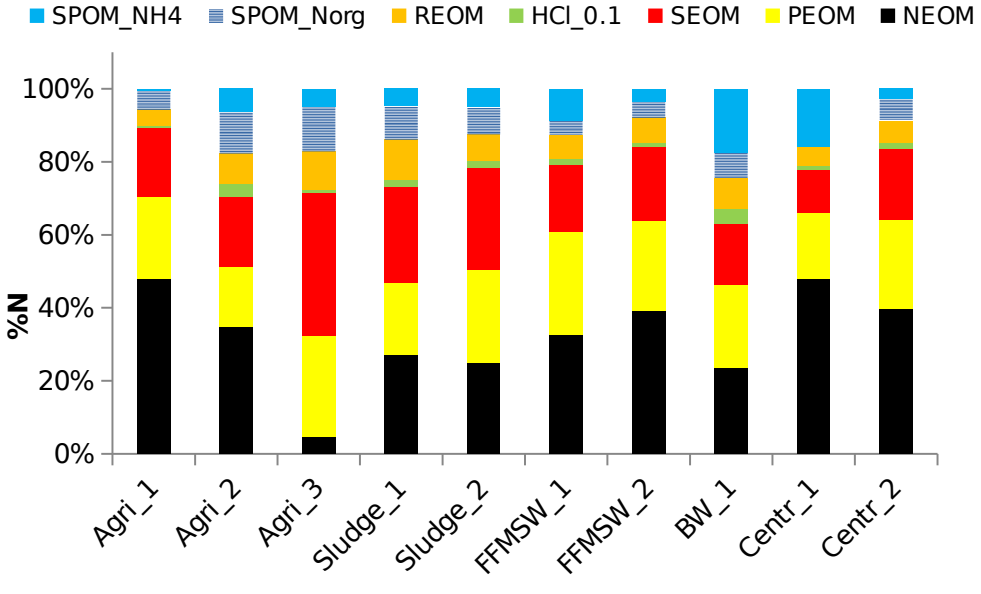




Results

Digestates P and N speciation



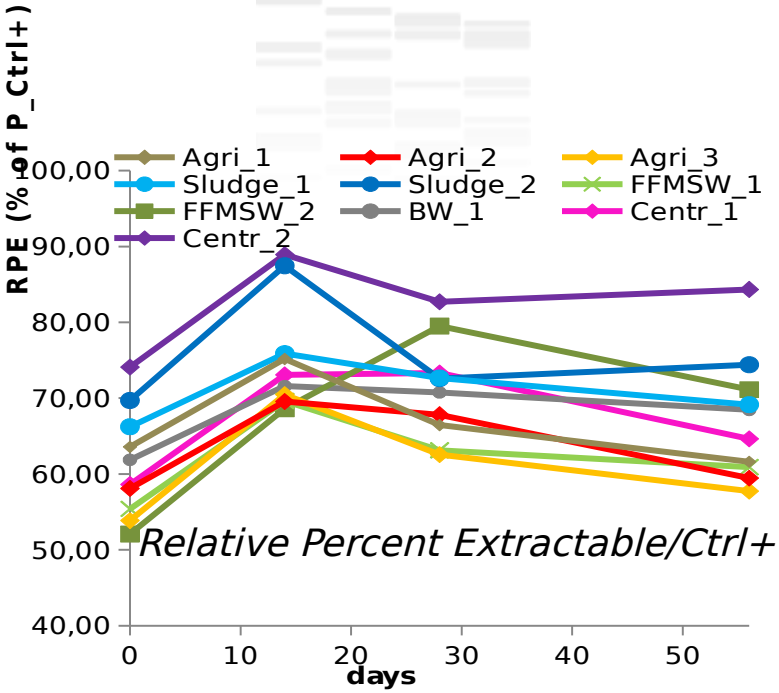


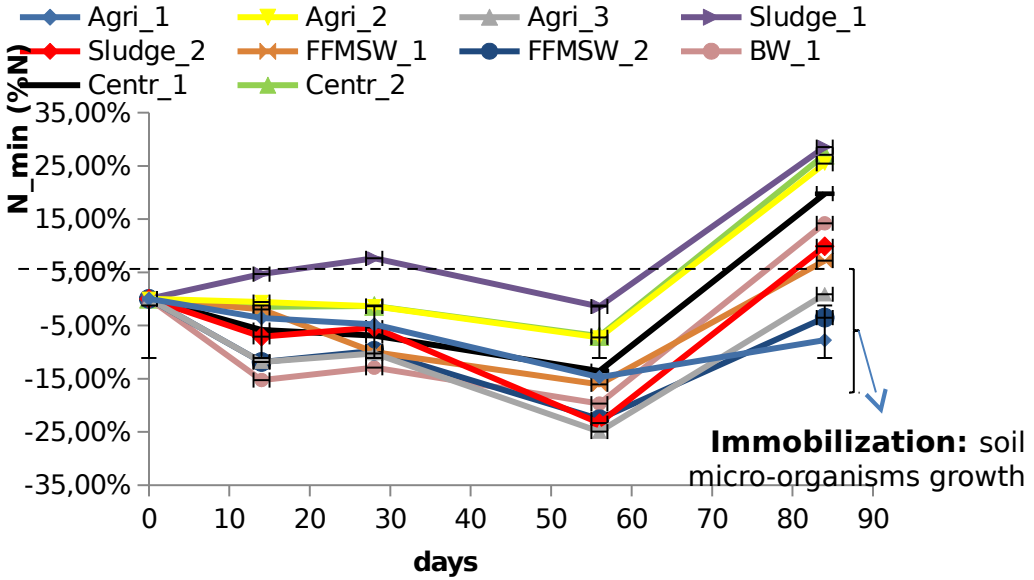
Grigatti et al. 2019

Different patterns of speciation -> different N and P recovery by plants?

Results

Soil incubation: P evolution





Digestates treatment **50-90% of the Chemical P** performance, poor fixation -> availability for plant!
P fixation occurs for Agri_1, 2 and 3 and FFMSW_1

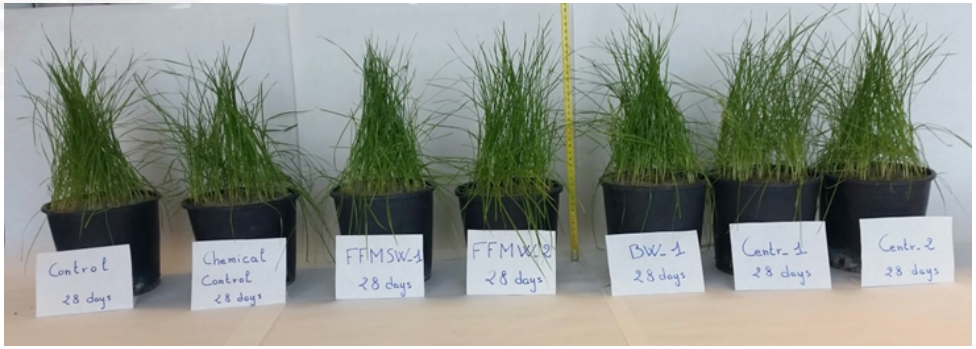
RPE and Organic Water-P correlated **(r=-0.68, p<0.05)**

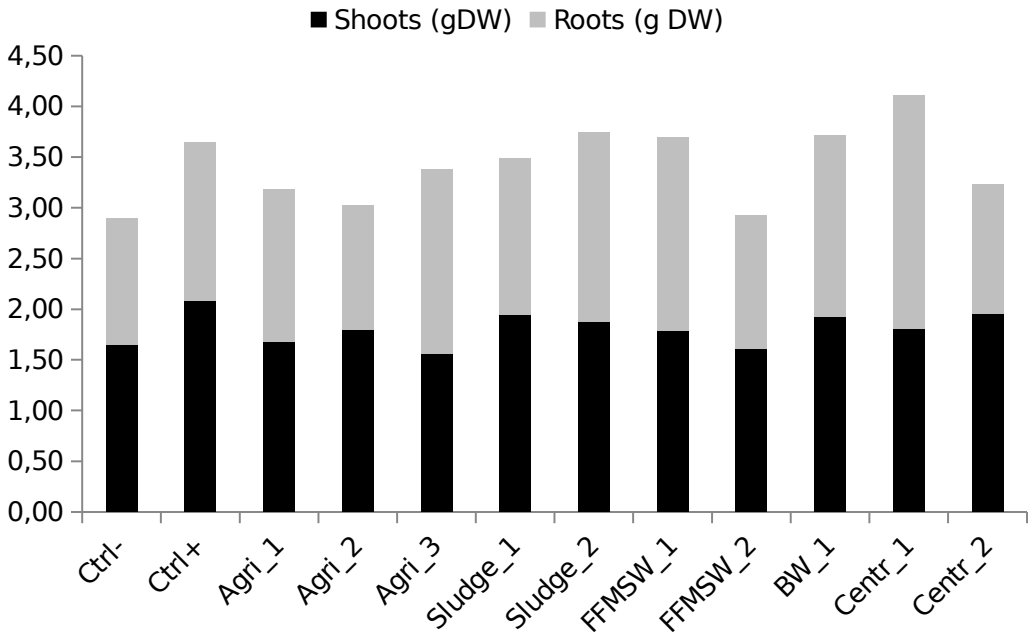
High Immobilization of N for soil microorganisms growth: freeze-dried samples use *(a lot of available NH4 removed!)*

Mineralized N correlated negatively with C/N and PEOM (N from holocellulose-like extraction)
(r=**-0.72, -0.58 respectively, p<0.05)**

Results

Plant pot tests: total biomass harvested (gDW)





Low tissue: Agri_2, FFMSW_2
close to ctrl-
High tissue: Centr_1, BW_1

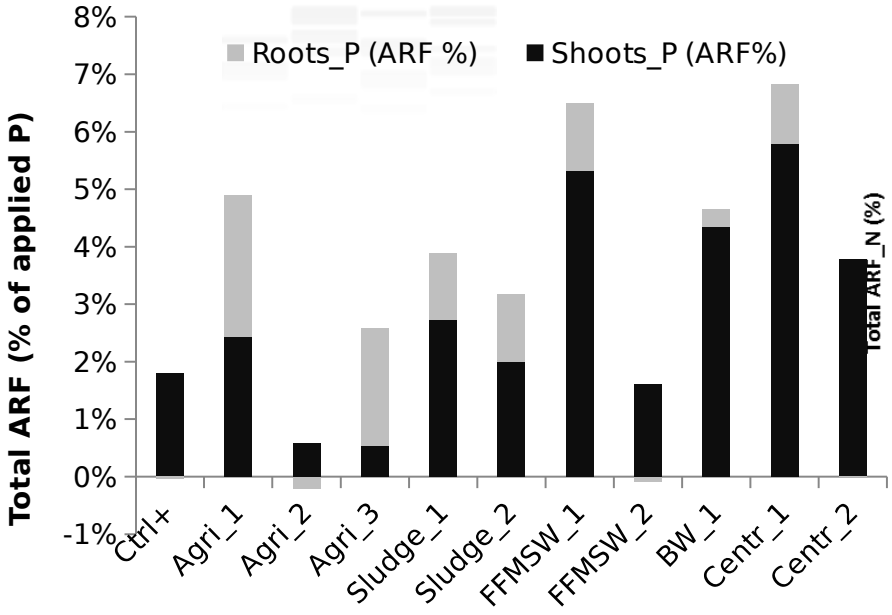
No signicificant difference on shoots and roots : Kruskal-Wallis test p=0.89 and 0.23 respectively

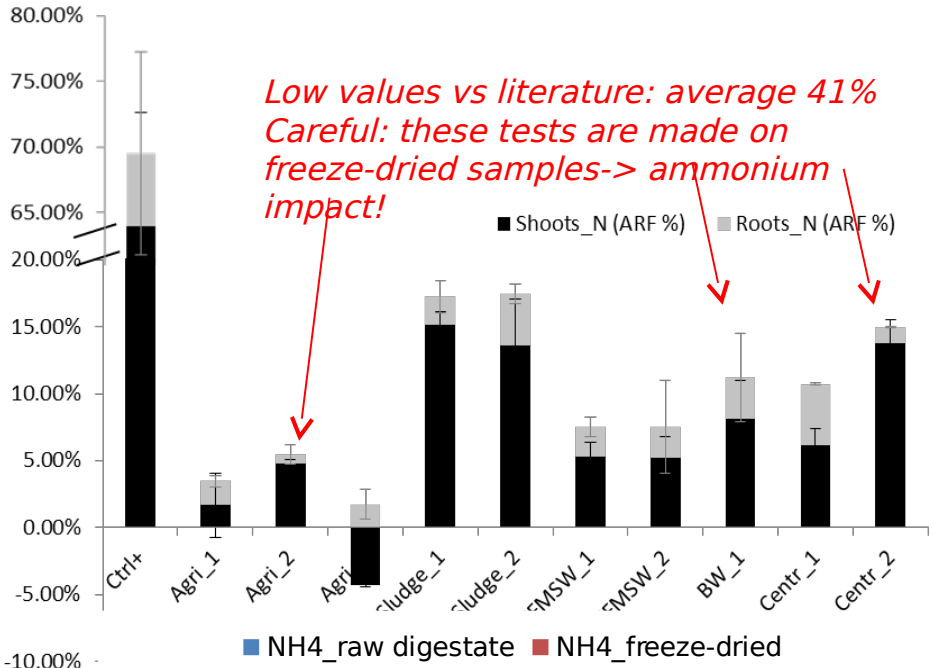
Results

Apparent Recovery Fraction (ARF)

$$ARF\,(\%) = \sum_{i=1}^{n} \frac{C\ uptake\ treatment_{ti} - C\ uptake\ ctrl_{-ti}}{C\ added} \times 100$$

Plant pot tests: P on plant tissues

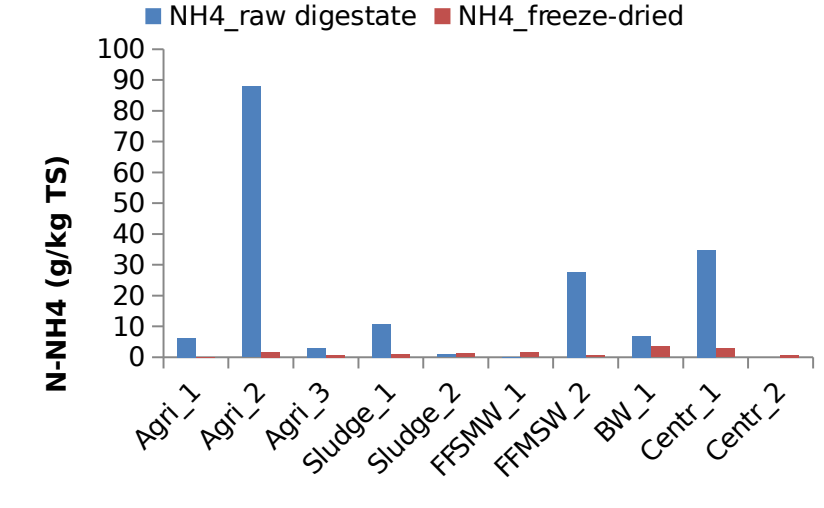




Low values vs literature: average 41%
Careful: these tests are made on freeze-dried samples-> ammonium impact!

Equivalent chemical nutrient: K_eq_P > 100%; except Agri-2- >35%

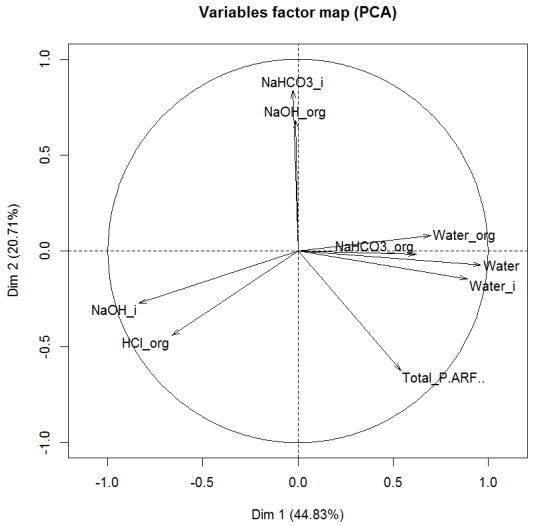
Centr_1>FFMSW_1> BW_1 >
Agri_1>Centr_2>Sludge_1>Sludge_2>
Agri_3> FFMSW_2>Agri_2

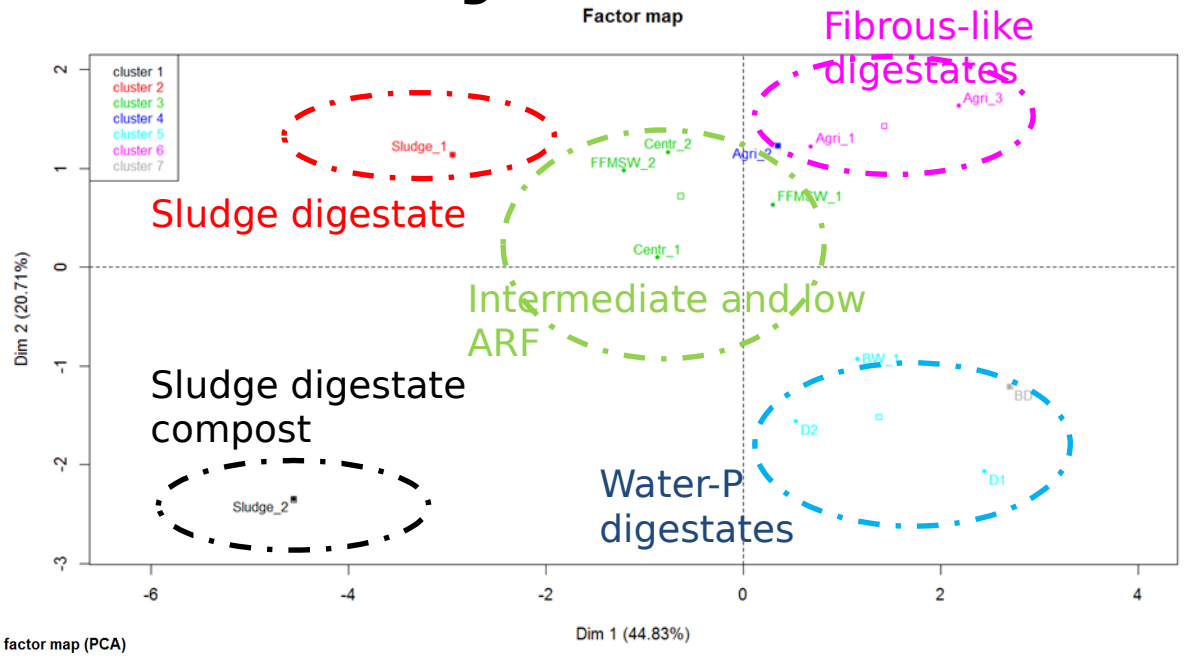


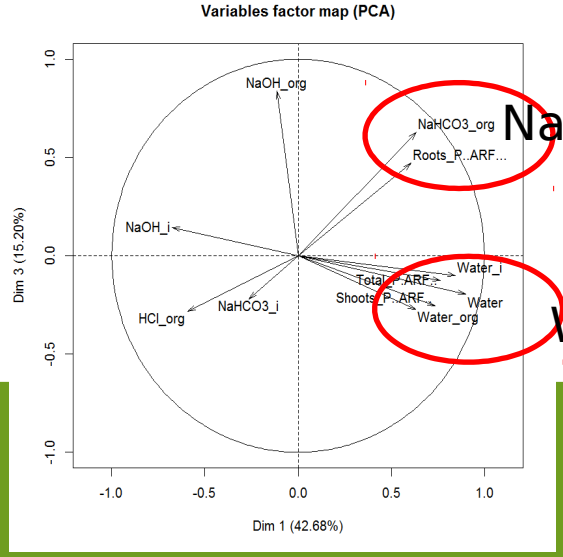
Plant growth was affected by all the treatr
(Kruskall-Willis, p < 0.021)
Plant growth was affected by all the treatr
Willis, p=0.021)

Results

Plant pot tests: correlations with P digestates characteristics







NaHCO3_org (r=0.62, p=0.025)

Water-P (r=0.49, p=0.09)

Results

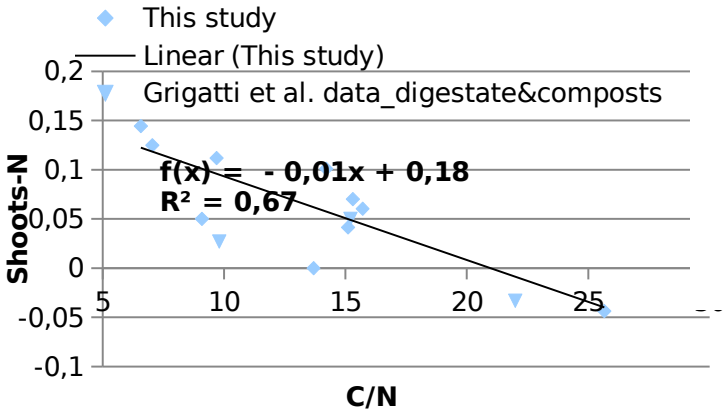
Plant pot tests: correlations with N digestates c

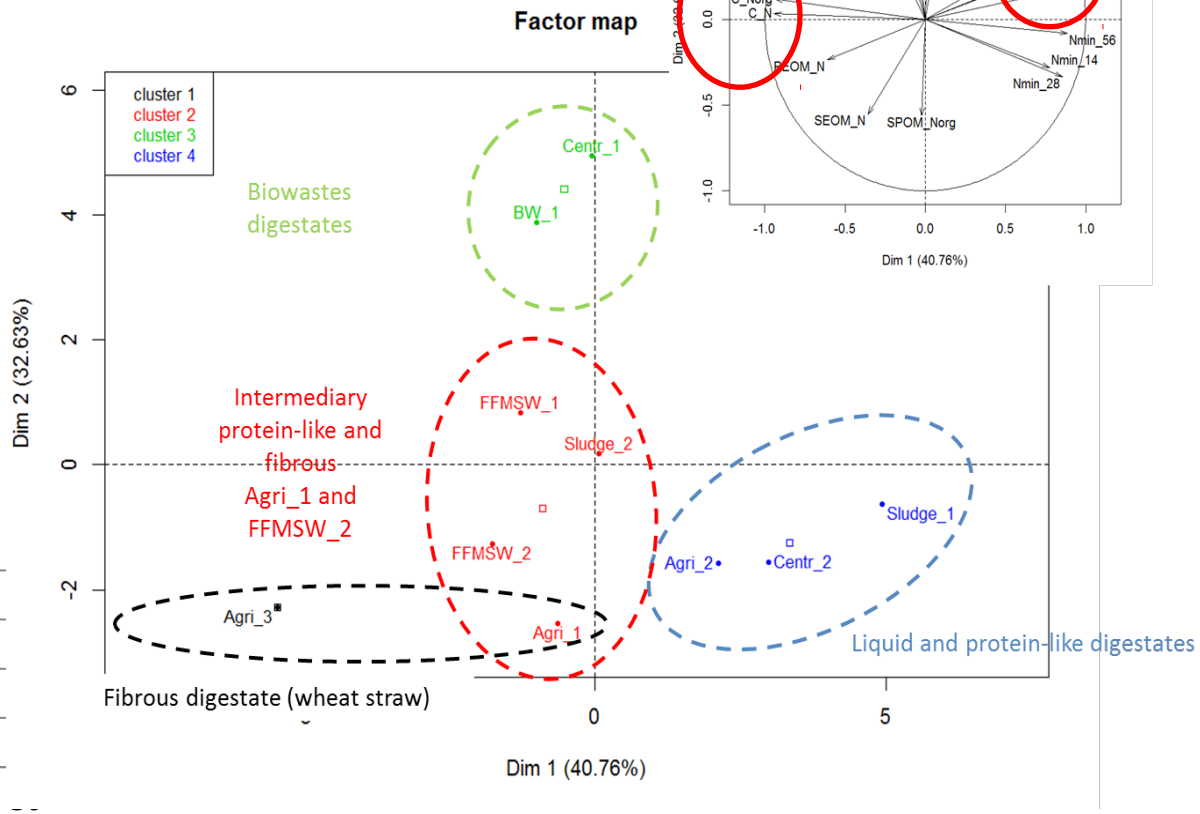
Nitrates (r=0.72, p=0.017)

SPOM_NH4 (r=0.61, p=0.062)

SPOM_Norg (r = -0.59, p = 0.067)

C/N (r=-0.82, p=0.004)





Take-home messages

- N and P accessibility speciation of digestates vary
  - according substrates nature (typology)
  - have an impact on soil incubation and nutrient recovery
  - Are correlated to nutrient recovery by soil and plants!

- Apparent nutrient recovery by plants
  - Shoots-P: correlated with Water-P (soluble and most available P)
  - Roots-P: correlated with organic NaHCO3-P (Olsen-P, labile P)

  - Shoots-N: correlated with C/N and PEOM-N (fibrous characteristic)
  - Roots-N: correlated with SPOM-NH4 and Nitrates (soluble and most inorganic N)

- **Need to**
  - validate this tendency
  - soil incubation with not prepared samples -> no evident conclusion for N plant recovery
  - Use the speciation to control fertilizers addition
  - Similar strategy for micropollutants (organic, biological, metals) and others negative parameters which have an impact on environment

Thank you for your attention

Acknowledgements
This project is supported by Agropolis Fondation under the reference ID 1502-302 through the « Investissements d'avenir » programme (Labex Agro:ANR-10-LABX-0001-01) and is part of the EU-funded project AgreenskillsPlus.